A System for Managing Water in Fine Textured Soils

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ABSTRACT

A water management system, which compensates for erratic rainfall was tested on silty clay and silt loam soils in Louisiana. With monthly rainfall in the State varying from 0 to more than 375 mm and with annual average rainfall of about 1400 mm, a water management system which would drain excess water from the soil during rainy, wet periods and add water to the soil by subirrigation during droughts was needed. The system that was tested consisted of bordered areas in which subsurface drains were installed. The drains were connected to sumps equipped with pumps, valves, and switches for removing drain outflow. This same system was used for irrigation by adding water to the sumps causing the water table to rise into the root zone.

The system was first tested on 40 m² concrete bordered plots during 1967-1972 at Baton Rouge, LA, and later on 0.4 ha plastic bordered plots during 1979-1981 near Houma, LA. The success of the system was attributed to favorable water flow properties of the soil, borders which restricted the lateral movement of water to and from the bordered area, and the presence of a natural water table, usually within the top 1.2 m of the soil profile, which prevented excessive water losses due to percolation during irrigations.

INTRODUCTION

The Lower Mississippi Valley of the US has great potential for increasing food production and perhaps can play an important role in helping meet future national and international food needs. The favorable resources of the region include fertile soil, adequate water supply, and a long frost-free crop growing season during which two and perhaps three different crops may be grown in one year. A major obstacle that is preventing the region from reaching its crop production potential is the lack of good water management systems. Although annual total rainfall in the area is more than adequate to meet the evapotranspiration (ET) requirements, it does not always occur when needed. It is common for monthly rainfall to exceed ET by 25 cm and then a couple of months later find stress signs in crops due to drought.

A water management system which removes excess water from the soil profile during periods of high rainfall and adds water to the soil profile during droughts is needed. Such a system has been tried by many including Skaggs et al., (1972), Doty and Parsons (1977), Follet et al. (1974), and Benz et al. (1978). Fox et al. (1956) reported on the design of subirrigation systems.

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The purpose of this paper is to report the results of tests that were made to determine if a water control system could be used to successfully manipulate the water table in silt loam and silty clay loam alluvial soil.

PROCEDURE

Concrete bordered plots 40 m² in size, hereafter called the Ben Hur plots, were constructed on Mhoon silty clay alluvial soil on the LSU Ben Hur research farm in 1966. The perimeter of each plot was trenched to a depth of 1.70 m and forms were placed into which concrete was poured. The tops of the concrete borders were 0.3 m below the soil surface, deep enough not to interfere with normal disking, planting, and cultivating. Inside each plot, two 10-cm diameter clay tile drain lines spaced 2.7 m apart were installed 1.5 m below the soil surface. A sand and gravel envelope surrounded the clay tiles. The two drains were routed through the concrete perimeter wall and connected by pipe to a water level control sump (one sump/plot). Each sump was equipped with a water supply, drain, and valve for controlling the water level in the sump at any level within 1.5 m of the soil surface (Fig. 1). Water for the sumps was supplied by a nearby well. Several water regimes were tested with this system. The first test, with 12 plots, was to determine if water tables could be maintained 60, 80, 100, and 120 cm below the soil surface. Each of these water level treatments was replicated three times. In 12 other plots, tests were made to determine if water tables could be maintained 30, 75, and 120 cm below the soil surface. The water level treatments in this test were replicated four times. At the start of these tests, the water levels in the sumps were adjusted until the desired water levels in the plots were obtained. Afterwards the water tables in the plots were usually checked two or three times each week. If the water levels in the plots varied more than 3 cm, adjustments in the elevation of the drain outlet and

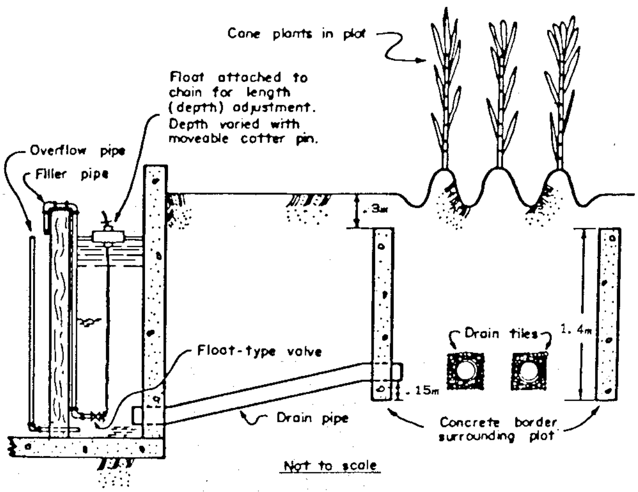

Fig. 1—Schematic of concrete bordered water management plots at Ben Hur.

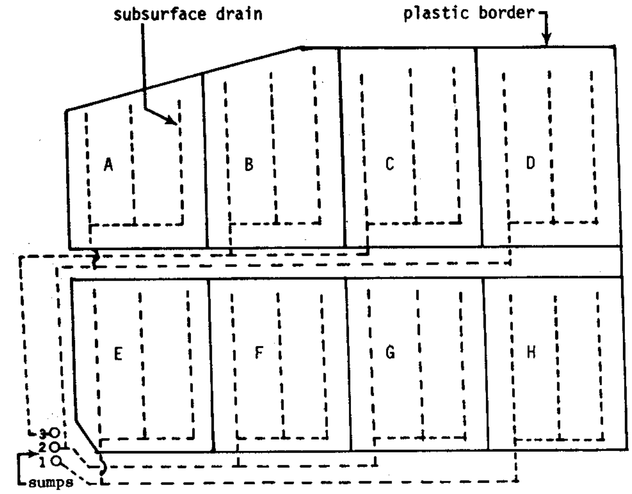

Fig. 2—Plastic bordered subsurface drained plot layout, Houma, Louisiana.

the float were made at the sumps to compensate for the difference.

A third soil water regime test was subirrigation. In this test, the moisture content of the soil in each plot was measured using the neutron probe technique. When two-thirds of the available water in the top 60 cm of soil was depleted, the water table was raised to the soil surface to wet the soil profile before lowering it again to 1.5 m. Moisture measurements were made before and after the subirrigations to determine their effectiveness.

In 1977, another system similar in concept to the concrete bordered plots but much larger in size, was installed on Commerce silt loam alluvial soil in Terrebonne Parish, near Houma, LA. These plots will be referred to in this paper as the Houma plots. This system consisted of eight 0.4 ha plots (Fig. 2), but instead of concrete borders, these plots were each surrounded with 6-mil thick polyethylene sheets installed beginning 0.3 m below the soil surface and continuing downward 1.8 m. A chain-type trencher was modified to install these borders. A metal housing, containing a verticle spindle for holding a large roll of polyethylene, was attached to the trencher just aft of the digging chain (Fig. 3). As the trench was dug around the perimeter of each plot, the polyethylene was discharged through a chute against the side of the trench which was backfilled immediately to hold the polyethylene in place. Inside each plastic bordered plot, three 10-cm diameter, corrugated, perforated, drain lines wrapped with Typar* filter material were installed 18 m apart and about 1.2 m below the soil surface with a laser equipped chain-type trencher. The drains in each plot were connected to a 15-cm diameter non-perforated, corrugated, plastic tube which was routed through the polyethylene border to the sumps. The 1.5-cm diameter sumps (pipes onto which bottoms were welded) were equipped with pumps, switches, and valves for controlling the water level. Four plots, A, D, F, and G, drained into sump 2; two plots, B and C, drained into sump 3; and two plots, E and H, drained into sump 1 (Fig. 2). The water levels in the sumps were controlled by floats on both the pump-control switches and on the solenoid valves. When the water level in the sumps was too high the pump was activated to remove water. When the water level in the sumps was too low the solenoid valve was activated to admit water, the source of which was a nearby swamp.

Several water regime tests were made. The first, in 1979, was to determine if a high water table could be maintained in one plot while a low water table was maintained in an adjacent plot. To evaluate the system, cased wells 13 mm in diameter were installed in two rows perpendicular to the drain lines in each plot. These wells were installed at a depth of about 1.2 m, one row of which was installed about 15 m and the other row about 60 m from the lower side of each plot. Along each row the wells were placed about 0.3 m from the plastic borders and about 1.8, 4.5, and 9 m between two of the three parallel drains, a total of 7 wells per row in each plot or 14 wells per plot. The float on the pump switch of the sump into which plots A, D, F, and G drained was set to keep the water level in the sump below the outlet of the main drain line. Sumps 1 and 3, into which plots E and H, and plots B and C drained, respectively, were not pumped. This arrangement provided four plots with high water levels and four plots with low water levels.

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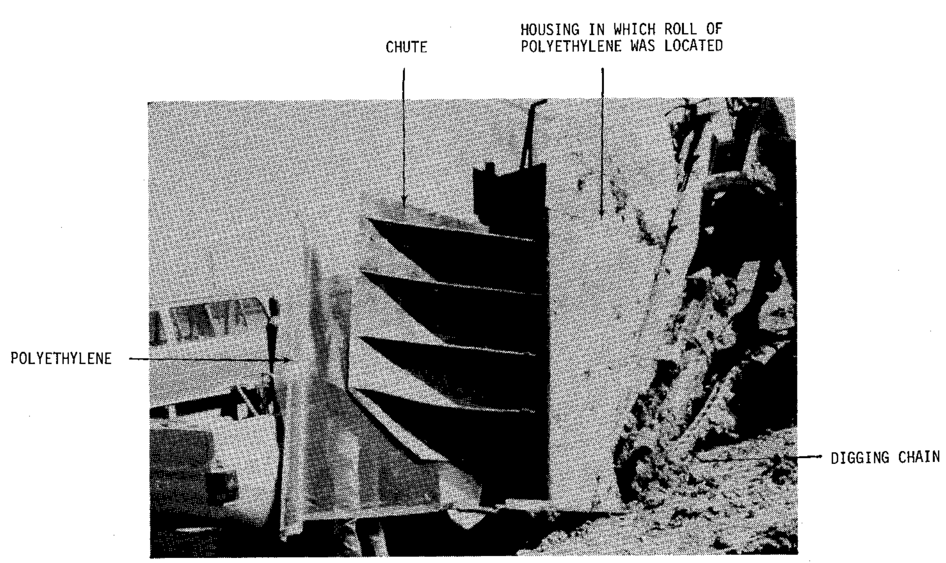

Fig. 3—Polyethylene was discharged through a chute from a roll mounted on a spindle inside the metal housing which was attached to the trencher just aft of the digging chain.

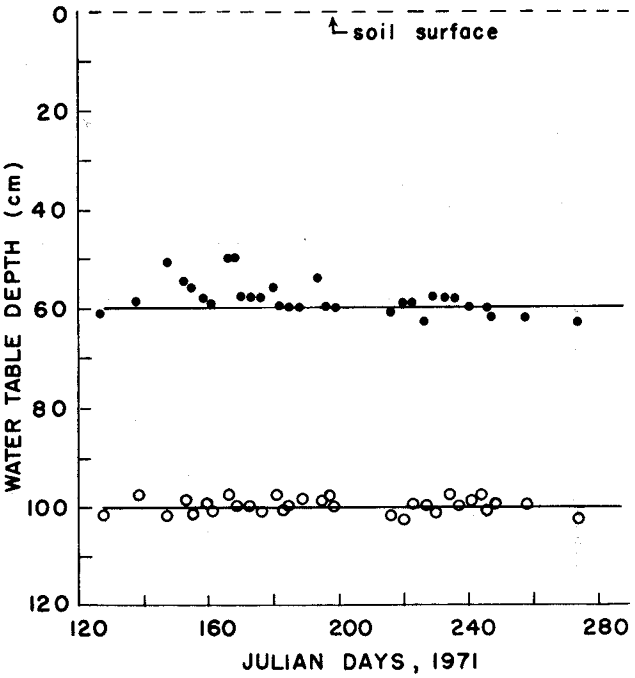

Fig. 4—Observed water table depths in Ben Hur plots with treatments 60 and 100 cm below the soil surface.

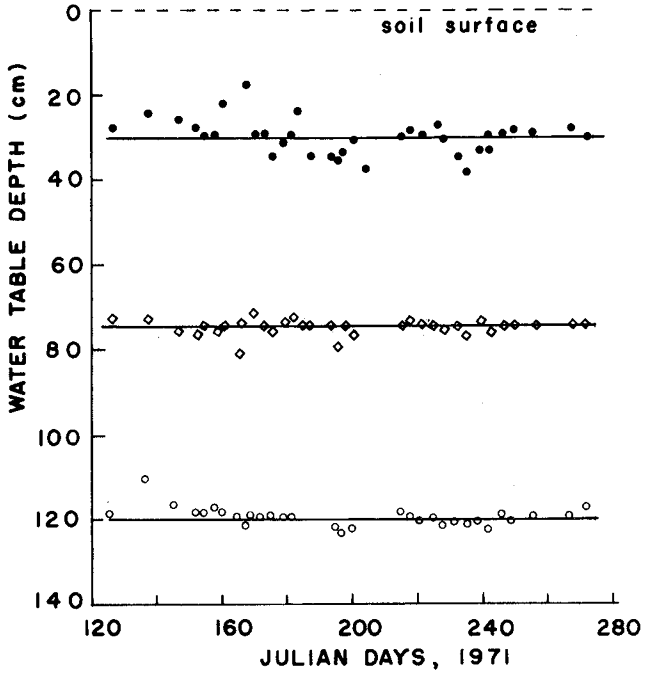

Fig. 5—Observed water table depths in Ben Hur plots with treatments 60, 75, and 120 cm below the soil surface.

Another test was made in 1980 during a drought. Water was pumped into sumps 1, 2, and 3 to determine if subsurface irrigation were possible during difficult subirrigation conditions which included a relatively low water table, a rapidly growing sugarcane crop with a high demand for water, and high evaporation. The water tables during this test were measured with water stage recorders located midway between two drains in each plot.

Additional similar tests were made with this system in 1981.

RESULTS AND DISCUSSION

Ben Hur Plots

The water levels in the Ben Hur plots were controlled reasonably well by water level control sumps to which the plots were connected. During a 5-year experiment, beginning in 1967, water levels were maintained near the desired level of 60, 80, 100, and 120 cm below the soil surface. In Fig. 4, data from two plots, one with a water table treatment of 60 cm and the other with a water table treatment of 100 cm below the soil surface, show how closely the water levels were controlled. Results from another test, with water table treatments 30, 75, and 120 cm below the soil surface, showed that the system was effective even at water tables as high as 30 cm below the soil surface (Fig. 5). The data in Figs. 4 and 5 were collected during periods when evapotranspiration and rainfall, two parameters which affect the water level, varied considerably. Daily evaporation, which can be used as an estimate of evapotranspiration, exceed 8 mm many times during the period. Maximum daily rainfall was 44 mm.

Standard error in the water table data ranged from 0.25 cm for the 100-cm water table in Fig. 4 to 1.07 cm for the 30-cm water table in Fig. 5. Similar results were obtained from the other plots in these experiments.

Although the sumps were equipped to control the water level automatically, it was not a simple matter of just setting the water level in the sump. Differences usually existed between the water level in the sumps and that in the plots. This difference varied depending upon rainfall amounts and evapotranspiration. The demand for water in the plots changed often and sometimes drastically. For example, during droughts, the demand for water in the plots was high, requiring extra head in the sumps to force the water to the desired level. During large rainstorms, the process reversed when the water levels in the plots became higher than those in the sumps. Such changes made it difficult to keep the water table at exactly the desired level. The data in Figs. 4 and 5 show, however, that in spite of varying conditions, the water tables were maintained relatively close to the desired level. Even closer control would have been possible if adjustments to the water level in the sumps had been made daily.

The system also worked well for subirrigation. During droughts in 1969 and 1970, the water table was raised to the soil surface to provide growing sugarcane with water. During these irrigations the outline of the plots could be easily observed by the moist soil. In some cases, water ponded on the surface. In addition, soil moisture, measured with a neutron probe, indicated that the soil was wetted by subirrigation (Fig. 6).

Data indicated that the system was excellent for managing water during the three experiments discussed here as well as during several other similar experiments conducted in the early 1970's (Carter and Floyd, 1975, and Carter, 1980). Raising the water table to near the soil surface became difficult, however, by 1975. Extensions on the sumps were installed so extra head could be provided to force water to the desired level in the plots. In 1977, inspections of the drain lines in several plots revealed that the lines were partially clogged with sediment, thus the reason for difficulty in raising the water table. Because of this, the drains in all 48 plots

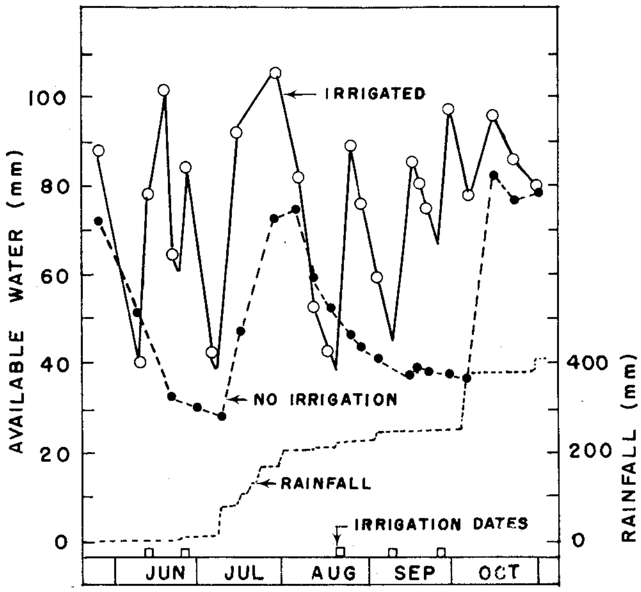

Fig. 6—Available water in top 0.6 m of soil, accumulated rainfall, and irrigation dates during 1969—Ben Hur plots.

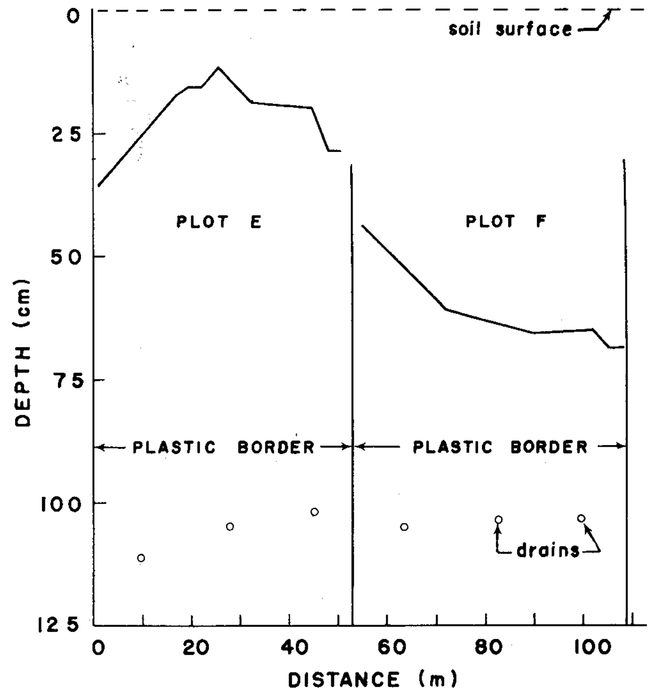

Fig. 7—Water table elevation in Houma plots E (high water table treatment) and F (low water table treatment). June 7, 1979.

were replaced during 1977 and 1978 using 10-cm diameter perforated, corrugated, plastic tubing wrapped with a synthetic filter and surrounded with a coarse sand envelope. Tests conducted soon after installation and several years later (1980 and 1981) showed that the system was again operating satisfactorily.

Houma Plots

The first test with the Houma plots was to determine the effectiveness of the system in providing different water levels in the plots and in reducing flow from one plot to the one adjacent. Data in Fig. 7 show the effectiveness of the system in providing differences in the water table; a difference of about 50 cm is shown. Differences in high and low water tables in the other three pairs of plots were similar. Data in Fig. 7 also show that the plastic borders reduced horizontal flow since there was a change in the water level across the border. The sloping water table in plot F, however, indicates that some water continued to flow from plot E. Data from plots C and D did not show such a sloping water table, indicating the plastic border was more effective in reducing horizontal flow between those plots. One possible reason for the plastic barrier being more effective in one place than in another may be due to sand lenses. Lenses are fairly common in Commerce silt loam. A plastic barrier crossing over a sand lens without passing completely through it (vertical direction) could result in water easily passing through the sand around the lower edge of the barrier and into the adjacent plot. Another likely reason is that water flowed from plot E over the top of the plastic border into plot F. Note in Fig. 7, the water table in plot E was slightly above the plastic border between plots E and F.

In August 1980, the system's potential for subirrigation was evaluated. Water was added to the sumps to subirrigate during a drought. The water table midway between the drains rose readily about 90 cm to within 45 cm of the soil surface (Fig. 8). This provided water well within the root zone of a sugarcane crop which was growing on the plots at that time. To determine the distribution of the water table within the plots, small observation wells were augered at eight different locations in plots E and H. The water table depths varied from 10 cm near the drain lines to 45 cm midway between the drains. Closely controlled constant water tables like those in the Ben Hur plots were not attempted in these larger plots. It was evident from the initial tests that these large plots could not be controlled as closely as the water table was in the small plots. Closer drain spacings would be required for closer water table control.

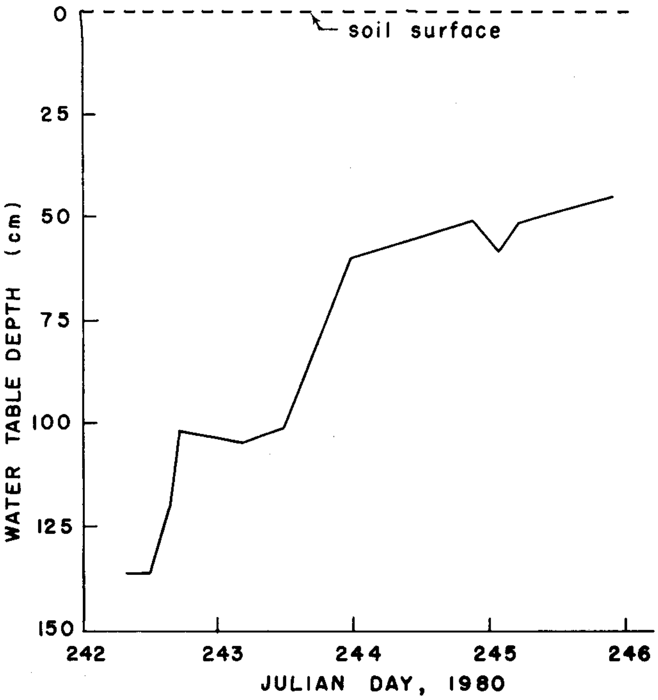

Fig. 8—Rise in water table in Houma plot H due to subsurface irrigation beginning August 29th (Julian Day 242), 1980.

In January 1981, high water table treatments on four plots and low water table treatments on four other plots were tested again. The water table measurements were not as elaborate as those in 1979—only one water stage recorder per plot was used. Data showed a difference of 60 cm between high and low water table treatments, which was similar to the difference measured in 1979.

Success in raising the water table nearly to the soil surface is attributed primarily to the natural water table which was usually within the top 1.2 m of soil. Water table measurements over the years indicate that the water table in the area seldom drops below 1.8 m. With a water table this close to the soil surface, no serious problems in raising the water table for subirrigation should occur due to deep percolation. The plastic borders were also helpful in raising the water table by reducing horizontal flow. This particular soil has a silt layer about 1.2 m below the soil surface through which water may flow readily. Placing a barrier across this silt layer confines much of the water to within the plastic borders thus making it easier to raise the water table.

Success with this water management system has enhanced the potential for increasing crop yields in the lower Mississippi Valley. Test results reported in this paper show that the water management system concept works in silt loam and silty clay; it removes water from the soil profile during wet periods and adds water to the soil profile during droughts. The key to obtaining maximum benefits from this water system, however, is management—knowing when to activate the system for drainage and for irrigation. Progress is being made on this aspect: experiments are underway to help answer these questions.

Advantages to a combination subsurface drainage—subirrigation system include: (a) initial costs are less than those for separate drainage and irrigation system, (b) the system is convenient to operate since drainage or irrigation can be initiated by activating switches and valves, and (c) irrigation may be accomplished without wetting the soil surface, thus permitting other farm operations such as pesticide applications or cultivations to be done simultaneously with irrigation. Disadvantages include: (a) extra pumping costs may be required for irrigation due to having to raise the water table to irrigate, and (b) initial investment may be high.

SUMMARY

A water management system, consisting of subsurface drained, bordered plots which were connected by pipe to water level control sumps, was tested during 1967 through 1981. At first, the system was tested on a small scale using 40 m² plots on silty clay alluvial soil near Baton Rouge, LA. Later the system was tested on larger 0.4 ha plots on silt loam alluvial soil near Houma, LA. The results from these tests showed that the system could be used effectively to manipulate the water table in the soils tested. Excellent water table control was obtained on the small plots. Although the water table in the large plots could not be controlled as closely as those in the small plots due to differences in drain spacing, relatively good water table control was obtained. The system was also used effectively to subirrigate the large plots during a very difficult period when, during a drought, the water table was relatively low and evapotranspiration was high.

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